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QUARTERLY UPDATE DECEMBER 31, 1977

TECHNOLOGY APPLICATION CENTER
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO 87131

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HEAT PIPE TECHNOLOGY

A BIBLIOGRAPHY WITH ABSTRACTS

QUARTERLY UPDATE

OCTOBER-DECEMBER 1977

ASSEMBLED BY

THE HEAT PIPE INFORMATION OFFICE

OF

THE TECHNOLOGY APPLICATION CENTER
INSTITUTE FOR APPLIED RESEARCH SERVICES
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO

JANUARY 1978

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INTRODUCTION

This is the fourth quarterly update for 1977 in Heat Pipe Technology.

The major portion of this quarter's activity has been in the area of heat pipe applications for energy conservation and solar energy related systems. An increased number of publications in the areas of electrical and electronic applications of heat pipes also appear in this issue.

The bibliography has undergone some revision, with section II B now entitled Energy Conversion and Power Systems, and section II C now entitled Energy Conservation, Solar, Nuclear and other Energy Systems. These new sections result from our effort to maintain the bibliography within today's categories of interest, and to encompass the trend which heat pipe technology is currently setting.

We would also like to inform our subscribers that the bibliography is now being compiled utilizing an increased amount of computerized literature searching with the most prominent and complete engineering and science data bases being accessed.

We at TAC hope that our efforts are helping to make this a more complete and reader responsive publication, and we would appreciate comments or suggestions which would contribute to this effort.

Gilbert A. Rivera
Technical Editor

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**Citation numbers appear on upper right corner of each page

GUIDE TO USE OF THIS PUBLICATION

A number of features have been incorporated to help the reader use this document. They consist of:

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I. GENERAL INFORMATION, REVIEWS, SURVEYS

HP77 10006 REQUIREMENTS FOR U.S. HEAT PIPE EXPERIMENTS ON SPACELAB TEST FACILITY - Final Report

Almgren, D.W., (Arthur D. Little, Inc., Cambridge, MA), May-Oct 1976, (Contract NAS5-23391), Sponsored by Goddard Space Flight Center, Greenbelt, MD
Avail:TAC

ESA is planning to supply a heat pipe test facility as part of the first Spacelab mission, scheduled to be launched in the third quarter of CY 1980. Mr. S. Ollendorf of NASA GSFC has submitted a proposal to NASA Headquarters in which, as Principal Investigator, he will provide heat pipes from the United States to be tested on the European facility. This report contains the ideas and opinions of the U.S. heat pipe investigators who responded to NASA's request for suggestions for experiments to be performed on Spacelab I. The suggested program goals and organization were developed during informal interviews with the potential experimenters. Based on all of the information gathered, a candidate grouping of experiments has been suggested for the initial flight that would permit five of the twenty-six suggested experiment ideas to be tested.

(PROPOSAL, PROGRAM GOALS, POTENTIAL EXPERIMENTS)

HP77 10007 10TH INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE

(Newark, DE), (New York, NY), IEEE, Aug 18-22, 1975

The following topics were considered: Electrochemical Cells; LMFBR; Energy Storage; Solar Heating and Cooling; Nuclear Power System; Thermionic Energy Conversion; Photovoltaic Conversion; Topping Cycles; Unique Engines; Solar Power; Synthetic Liquid Fuels; Thermoelectric Systems; Isotope Power Systems; Wind Power; Biomedical Power; H_2: Space Power System; Heat Pipe Followed by Brayton Cycle Systems. 249 papers were presented.

(ENERGY CONVERSION, THERMODYNAMICS, OVER-VIEW)

HP77 10008 HEAT AND MASS TRANSFER BIBLIOGRAPHY-SOVIET WORKS

Luikov, A.V., Int. J. Heat and Mass Transfer, (GB), V 18:697-705, N5

This bibliography of Soviet Works covers the following: Thermodynamics; Thermophysical Transport; Hydromechanics; Forced Convection; Natural Convection; Capillary-Porous Bodies; Phase Conversions; Radiation; Combined Heat and Mass Transfer; Rheophysics; Heat Pipes; Heat and Mass Transfer.

(REVIEWS, HEAT TRANSFER, FLUID FLOW, THERMODYNAMICS)

HP77 10009 THERMAL CONTROL BY HEAT PIPES

Oshima, K., (Soc. of Instrument and Control Engrs., Tokyo, Japan), J. Soc. Instrum. and Control Eng., Japan, V 14:662-670, N9

No abstract available

(REVIEW, THERMAL CONTROL)

HP77 10010 HEAT EXCHANGERS

Schmidt, E.L., Eisenmann, G., Hahne, E., (Inst. Fur Thermodynamik and Warmtech. Univ. Stuttgart, Stuttgart, Germany), Brennst.-Waerme-Kraft, (BWK), Germany, V 28:169-171, N4

Literature survey dealing with heat exchangers, including: Augmented Convective Heat Flow, Radiative Heat Transfer at High Temperature, Design Calculations Techniques, Heat Pipe Porous Heat-Exchanger Technology, Heat Recovery Schemes, Regenerators, Materials, Operating Experience and Optimisation of Cooler/System Matching.

(REVIEWS, HEAT EXCHANGERS, HEAT TRANSFER)

HP77 10011 ANNUAL REVIEWS

Van Dyke, M., Vincenti, G., Annual Review of Fluid Mechanics, Palo Alto, CA, V 7

A collection of review papers on the following: Fluid Mechanics, Delft University; Turbulent Boundary Layers; Nonlinear Thermal Convection; Relaxation Methods in Fluid Mechanics; Granular Flow; Flow Lasers; Vortices; Heat Pipes; Oceanic Waste-Water Disposal; Navier-Stokes Equations; Rotating and Stratified Flow; Turbulence; Large Lake Hydrodynamics; Wave Effect on Rubble-Mound Structures.

(REVIEW, THERMODYNAMICS, HEAT TRANSFER, FLUID FLOW)

HP77 10012 ALASKA PIPELINE SPINOFFS

Weismantel, G.E., Chem. Eng., NY, V 81:42-44, N6, Mar 18, 1974
No abstract available

(TRANSPORT, ENGINEERING, MARKET)

II. HEAT PIPE APPLICATIONS

II. A. GENERAL APPLICATIONS

HP77 20032 WETTING BY SODIUM AT HIGH TEMPERATURES IN PURE VAPOUR ATMOSPHERE

Bader, M., Busse, C.A., (EURATOM-JRC, Ispra (Va.), Italy), Journal of Nuclear Materials, V 67:295-300, Feb 1977
Avail:TAC

The wetting angle of sodium on different pure metals (Ni, Ta, Nb, Mo, W), alloys (stainless steel 304L, Inconel 600, RTG36, TZM) and oxides (Feldmühle E37, Degussa AL23, sapphire, ZrO_2, Y_2O_3) was measured in the temperature range from 520 to 720°C. A new measurement method was applied consisting of a combination of the classical sessile drop with a gas controlled heat pipe. The method is especially suited for high temperatures where the previous methods are impracticable because of excessive sodium evaporation. In the temperature range mentioned all investigated materials are wetted. The maximum measured wetting angle is 7.5°C. The wetting angles are nearly independent from temperature, but they show a time-dependency consisting in general of a rapid initial decrease and a reaching of the equilibrium value after about 1 hour.

(GAS CONTROLLED HEAT-PIPE, WETTING ANGLE, METALS, SESSILE DROP, TESTING)

HP77 20033 PREPARATION OF VAPOR GROWN LEAD-TIN TELLURIDE FOR 8-14 MICROMETER PHOTO-DIODES

Bradford, A., Wentworth, E., (Night Vision Lab., Fort Belvoir, VA), Infrared Phys., (GB), V 15:303-309, N4, A76-22930

Single crystals of lead-tin telluride ($Pb_{0.8}Sn_{0.2}Te$) 19 mm in diameter and up to 25 mm long have been grown by a closed-tube seeded vapor transport method. The crystals were grown in furnaces equipped with isothermal 'heat pipes' which provide convenient control of the temperature profile during growth. Growth rates of 2-2.5 g/day were utilized. Scanning x-ray topography analysis revealed good crystallinity. Wafers cut from the crystals were annealed to a carrier concentration $1-2*10^{17}$ cm^{-3} and mobilities of $2-3*10^4$ $cm^2/v\text{-}sec$ (p-type, 77K). Photodiodes formed from this material had peak detectivities of $2*10^{10}$ cm $HZ^{\frac{1}{2}}$ w^{-1}.

(HEAT PIPE FURNACE, SEMICONDUCTOR GROWTH, TEMPERATURE CONTROL)

HP77 20034 REALISATION OF A MONOMODE LASER IN A HEAT PIPE OVEN ON THE LAMDA#1.5 MUM LINE OF BARIUM

Cahuzac, P., Drago, X., (Lab. AIME Cotton, CNRS II, Orsay, France), Opt. Commun., Netherlands, V 18:600-602, N4, A77-003570
Avail:TAC

The article describes the properties of laser effect observed in a vapor provided in a heat pipe oven. The oscillation is pulsed and occurs on the barium line at 1.5 mum. with pulse duration of 20 ns.

(HEAT-PIPE OVEN, GAS LASERS)

HP77 20035 INTERCALIBRATION OF TEMPERATURE TRANSDUCER WITH A HEAT PIPE FURNACE. TEMPERATURE MEASUREMENT, 1975. TEDDINGTON, MIDDX. LONDON, ENGLAND

Coville, P., Laurencier, A., Billing, B.F., Quinn, T.J., (Soc. Anonyme D'Etudes et Realisations Nucleaires, Sodern, Suresnes, France), A76-07490
Avail:TAC

A heat pipe furnace is described in which channels are provided to accommodate a number of thermocouples or resistance thermometers for comparison. These channels are isothermal, and temperatures are constant over several hours. The temperature reached by the system when heated from room temperature is always the same within a few tenths of a degree centigrade without reference to another temperature transducer. This property is compared to the fixed point obtained by freezing of pure metals or compounds.

(HEAT-PIPE FURNACE, CALIBRATION, ISOTHERMAL, TEMPERATURE TRANSDUCER)

HP77 20036 'THERMAL CONDUCTION PIPE' AND ITS APPLICATIONS

Elektronik, Germany, V 24:101-102, N11
Avail:TAC

The principle of the heat pipe is described consisting of a sealed copper tube stainless steel or special glass, evacuated and containing a small amount of a special liquid; the inner wall is coated with a porous material, which acts as a wick. When one end is heated, the liquid boils, its vapour condenses at the cold end and is conducted back by the capillary porous layer, thus operating a heat transfer. The pipe is not a cooling element but a thermal conductor, of use in semiconductor heat sink applications. Several designs of tubular, flat and ribbed devices are described. Of particular interest is the isothermal oven 'Calocoax' by Philips, which consists of two coaxial, welded-together heat pipes, with a metal gauze capillary lining and an additional heater filament. The oven is intended for diffusion processes in semiconductor manufacture and is set apart by its uniform and closely controlled temperature.

(HEAT SINKS, ISOTHERMAL OVEN, SEMICONDUCTORS)

HP77 20037 ANALYSIS OF A HIGH-HEAT-FLUX WATER HEAT PIPE EVAPORATOR - Technical Report

Feldman, K.T., Jr., Berger, M.E.
Avail:TAC
No abstract available

(COMPUTER PROGRAM, NUMERICAL ANALYSIS, HEAT EXCHANGERS)

HP77 20038 LASER PHOTOLUMINESCENCE OF Bi_2

Gerber, G., Sakurai, K., Broida, H.P., (Dept. of Phys. Univ. of California, Santa Barbara, CA), J. Chem. Phys., V 64:3410-3422, N8, A76-60899
Avail:TAC
A heat-pipe oven has been used to produce molecular bismuth. Strong luminescence has its origin in various vibrational-rotational transitions of the A-X system. It is suggested that A is not the first excited state and that X does not represent the ground state. Spectra are also presented using white light. Both line and continuum spectra are reported.

(HEAT-PIPE OVEN, PHOTOLUMINESCENCE, LINE SPECTRA, INERT GAS-FLOW)

HP77 20039 LINE-TERMINAL CONSTRUCTION TO BE COMPLETED BY MID-YEAR

Ives, G., Jr., Pipe Line Ind., V 46:31-33, N1, Jan 1977
Avail:TAC
Alyeska Pipeline Service Co. reports the final section of the 1287-km (800-mile) Trans-Alaska Pipeline was laid last month in rugged Thompson Pass, 32.1 km (20 mi.) northeast of the Valdez Terminal. The pass is only 88 km (55 mi.) north of the Tonsina River, where the first sections of pipe were installed March 27, 1975. Even though all sections of the pipeline are in place, not all are connected by welds. Overall, the project is 91 percent complete and the pipeline itself is 97 percent complete. Start-up for the project is targeted for early summer. Interestingly, the project presented a number of firsts in pipeline construction. For example, the Trans-Alaska Line was the first to: use an internal weld inspection and repair vehicle; use a special refrigerant burial system; use a microwave network, as well as a satellite earth system; have sections constructed in an insulated box; utilize a cableway in construction; have primary pump stations enclosed in buildings; and have an above-ground pipeline system employing thermal devices to remove heat from the ground and use airborne infrared to monitor the heat pipe system.

(ALYESKA, PERMA-FROST, AIRBORNE-INFRARED-MONITOR)

HP77 20040 APPLICATIONS OF HEAT PIPES

Kikuchi, K., Arisawa, K., Yuwata, Z., Matsumoto, K., (Furukawa Electric Co. Ltd., Tokyo, Japan), Furukawa Electr. Rev., Japan, p. 67-80, N56, B76-15887
Avail:TAC
Explains the principles, working limits, working modes, etc. of the heat pipes superconductors of heat. Also introduced are some examples of the practical use of the tube, centering on its application in NASA's space development, and for cooling of large-capacity semi-conducting elements.

(HEAT SINK, APPLICATIONS, OVERVIEW)

HP77 20041 CURRENT ACTIVITY IN APPLIANCE DESIGN

Kirk, W.B., (American Gas Association Labs., Cleveland, OH), Institute of Gas Technology, Chicago, IL, 1974, Proceedings of the Third Conference on Natural Gas Research and Technology.
Avail:TAC

Factors affecting the design of more efficient appliances are presented, followed by a brief synopsis of recent and new projects aimed at conserving energy. Examples of concepts for achieving higher efficiencies are reviewed.

(CONSERVATION, HEAT PUMPS, FURNACES, REFRIGERATION, STOVES)

HP77 20042 GENERAL SUMMARY OF EFFICIENT USE OF FUELS IN PROCESS AND MANUFACTURING INDUSTRIES

Long, G.M., (Inst. of Gas Tech., Chicago, IL), 1974
Avail:TAC

April 16 to 19, 1974, the Institute of Gas Technology held a symposium in Chicago on efficient use of fuels in the process and manufacturing industries. Increased efficiency has been necessitated by price increases, which, in part, have resulted from curtailments or interruptions of fuel supplies. Measures to attain more efficient fuel utilization are thus prompted by availability as well as price considerations. Some 30 speakers, singly and in panels, discussed the theme from the standpoints of fuel and price forecasts, economics, conservation, trade-association actions, monitoring of energy usage, controls, insulation, boilers, improved combustion, heat pipes, heat-storage wells, infrared heating, waste-heat recovery, alternative combustible gases, industry experience, fuel allocations, and government research. A general summary of the symposium as delivered by the symposium chairman in closing the conference is presented.

(CONSERVATION, INDUSTRIAL PLANTS, HEAT RECOVERY, ECONOMICS)

HP77 20043 THE HEAT PIPE COOLING SYSTEM FOR THE BRAKE EXCITATION CONVERTOR OF ELECTRIC LOCOMOTIVES

Lossel, W., Fries, P., Ruger, H., Elektr. Bahnen, Germany, V 46:33-36, N2, B75-18351
Avail:TAC

The heat pipe as a means of conveying and dispersing heat, is much smaller and lighter than the usual radiator; for example, to disperse the equivalent of 0.5 kW to 1.0 kW in heat loss, a heat pipe would weigh some 4 kg against 20 kg for the usual radiator. Tests are currently being conducted by the German Railways on locomotive convertors fitted with heat pipe cooling arrays.

(POWER CONVERTERS, COOLING, BRAKING)

HP77 20044 HEAT-PIPE-OVEN REACTOR (HPOR) STUDIES. II. FORMATION OF EXCITED CN IN THE Li-NF_3-CCl_4 TERNARY FLAME SYSTEM

Luria, M., Eckstrom, D.J., Benson, S.W., (Phys. Sci. Div., Stanford Res. Inst., Menlo Park, CA), J. Chem. Phys., V 65:1595-1596, N4, A76-88148
Avail:TAC

First observations of purely chemically produced electronically excited CN molecules from the NF_3-CCl_4-Li Ternary Flame System is reported. The reaction is studied in a heat pipe oven reactor, the light output in the range 2000 to 8000 Angstroms' being recorded. The composition of the emission spectrum is outlined and major features identified. Possible excitation mechanisms for production of excited CN molecules are discussed.

(SPECTRA, TERNARY FLAME, EXCITED MOLECULES)

HP77 20045 LASER PHOTOLUMINESCENCE OF CALCIUM MOLECULES

Sakurai, K., Broida, H.P., (Dept. of Phys. Univ. of California, Santa Barbara, CA), J. Chem. Phys., V 65:1138-1145, N3, A76-83032
Avail:TAC

A variety of laser lines have been utilized to excite photoluminescence spectra of Ca_2. The calcium was produced in diatomic form using a heat pipe oven, in the temperature range from 1000 to 1200°K. A number of the spectra are reproduced and their characteristics catalogued with sharp lines identified and associated with the known bound states of calcium. Characteristics of the spectra indicate the effects of dissociation of excited molecules, emissions to repulsive parts of lower states and bound states.

(PHOTOLUMINESCENCE, HEAT-PIPE OVEN, SPECTRA)

HP77 20046 CHEMILUMINESCENCE OF CaH AND AlH IN THE REACTION OF THE METAL ATOMS AND FORMALDEHYDE

Sakurai, I., Adams, A., Broida, H.P., (Quantum Inst. and Phys. Dept. Univ. of California, Santa Barbara, CA), Chem. Phys. Lett., Netherlands, V 39:442-444, N3, A76-62685
Avail:TAC

Chemiluminescence from the reaction of calcium and aluminum with various hydrogen containing compounds in a flowing gas in a heat pipe oven are described. Red chemiluminescence of CaH was observed in the reaction of calcium, and weak chemiluminescence of AlH was seen in the reaction of aluminum with formaldehyde (H_2CO). It is proposed that a reaction between metal atoms and formaldehyde may be used as a source of diatomic metallic hydrides.

(HEAT-PIPE OVEN, FLOWING GAS SYSTEM, BOND ENERGY)

HP77 20047 TESTING STATIC SEALS AT HIGHER TEMPERATURES IN REAL CONDITIONS BY MEANS OF HEAT-PIPE TECHNIQUES

Verheyden, L.J., Schins, H.E., Kerntechnik, V 16:23-24, N1, Jan 1974
Avail:TAC

A method is described for testing global leaktightness of seals in a small and not expensive test rig based on the heat pipe principle, in which it is possible to create thermal shocks in both directions and to make long term tests. Two examples of applications are described with all details. In conclusion the advantages and disadvantages of the method are summarized.

(LEAKTIGHT TEST, TEST EQUIPMENT, THERMAL SHOCK)

HP77 20048 ARCTIC TUNDRA KEPT FROZEN BY HEAT PIPES

Waters, E.D., Oil Gas J., V 72:122-125, Aug 26, 1974
Avail:TAC

Alyeska Pipeline Service Co. has awarded McDonnell Douglas Corp. a $13 million contract to build nearly 100,000 heat pipes for the Trans-Alaska Pipeline. The heat pipes are cryo-anchor soil stabilizers (see gas abstr. 29,73-0686) designed to prevent thawing of permafrost around pipe supports for elevated portions of the line. These passive soil-refrigeration devices utilize an anhydrous ammonia process, with no moving parts or external power. Advantages include low overall cost, ease of installation, high reliability, versatility, adaptability to various supports, recoverability at end of short-term projects, prevention of gradual degradation and irrevocable losses of land and structures, and the possibility of retrofitting to correct developing problems.

(ALYESKA, PERMAFROST, CRYO-ANCHOR, SOIL STABILIZER)

HP77 20049 PIPELINES AND ACCESSORIES FOR DISTRIBUTION NETWORKS OF DISTRICT HEATING. PLANNING, CONSTRUCTION, CALCULATION

Ziegler, K., Eisenhauer, G., (VWEW, Frankfurt Am Main, F.R. Germany), 1974, In German

A short survey of the field of district heating engineering is presented.

(SURVEY, OVERVIEW, ENGINEERING)

II. B. ENERGY CONVERSION AND POWER SYSTEMS

HP77 21003 IMPROVING FUEL VAPORIZATION

Automot. Eng., NY, V 84:37-43, N6, June 1976
Avail:TAC

The application of a heat pipe to the fuel system of an automobile engine is discussed. The improvement in uniformity of the air-fuel charge in each cylinder will result in smooth engine operation on lean mixtures, lower exhaust emissions, and improved fuel economy. The design and operation of the vaporizing pipe are given, and some performance test data are presented.

(AUTOMOBILES, FUEL SYSTEMS, EVAPORATION, GASOLINE)

HP77 21004 THERMOELECTRIC POWER SYSTEM

Byrd, A.W.
Avail:TAC
A thermoelectric power system comprised of a heat source having a fluid inlet and outlet for receiving fluid at the inlet, heating the fluid, and providing it as a heated fluid at the said outlet. Each thermoelectric generator assembly is comprised of a fluid chamber, first and second heat pipes, a mounting device, a thermoelectric element radiation unit coupled to the second heat pipe, and a pumping device.

(THERMOELECTRIC, POWER GENERATION, POWER SYSTEM)

HP77 21005 COMPARISON OF HYDROGEN WITH ALTERNATE ENERGY FORMS FROM COAL AND NUCLEAR ENERGY

Cox, K.E., (New Mexico Univ., Albuquerque, NM, Dept. of Nuclear Engineering), Energy Convers., V 6:49-54, N1-2, 1976
Avail:TAC
Alternate energy forms that can be produced from coal and nuclear energy have been analyzed on efficiency, economic and end-use grounds. These forms include hydrogen, methane, electricity, and Eva-Adam, a 'chemical heat pipe' approach to energy transmission. The Eva-Adam system for nuclear heat appears to be economically competitive with the other energy carriers except over very large distances. The cost of hydrogen derived from coal is approximately equal to that of methane derived from the same source when compared on an equal Btu basis. Thermochemically derived hydrogen from nuclear energy shows a break-even range with hydrogen derived from coal at coal costs of from 33 to 80/English pounds per ton depending on the cost of nuclear heat. Electricity and electrolytically derived hydrogen are the most expensive energy carriers and electricity's use should be limited to applications involving work rather than heat. Continued work in thermochemical hydrogen production schemes should be supported as an energy option for the future.

(ENERGY CONVERSION, GASIFICATION, HYDROGEN, METHANE, ECONOMICS)

HP77 21006 HEAT PIPES FOR USE IN HIGH-BTU GASIFICATION OF COAL

Gillmore, D.W., Strimbeck, D.C., (U.S. Dept. of Interior, Bureau of Mines, Morgantown Energy Research Center, Morgantown, WV), 1971-1976, U.S. Dept. of Interior, Bureau of Mines
Avail:TAC
Evaluation of the Principle of using heat pipes to transfer heat to a fluidized-bed coal gasifier.

(COAL GASIFICATION, FUEL GAS)

HP77 21007 A TEST OF FUSIBLE INSULATION FOR A PROPOSED ISOTOPE POWER UNIT

Lackey, M.E., (Oak Ridge National Laboratory, Oak Ridge, TN), 78 p., 6 refs, Apr 1974, 2 figures, ORNL-TM-4422
Avail:TAC
In support of the isotope kilowatt program, evaluation tests of the full-scale simulated thermoelectric power generation system was made. The test was run with 6.5 in. of fusible insulation around the heat block-shield to determine the system heat losses. A test was run to determine the thermal coupling between the heat block-shield and 12 heat pipes with 12 simulated thermoelectric generators. A loss-of-coolant accident test was made to determine the maximum fuel capsule surface temperature reached during a meltdown of the fusible insulation.

(THERMOELECTRIC, POWER GENERATION, INSULATION, ISOTOPIC GENERATOR)

HP77 21008 ENERGY TRANSMISSION SYSTEMS

Leeth, G.G., (General Electric Co., Santa Barbara, CA), Int. J. Hydrogen Energy, V 1: 49-53, N1, 1976
Avail:TAC
Various methods of transporting large quantities of energy are compared. The energy source is assumed to be nuclear fission. However, expected significant effects of alternative energy sources are noted. The associated energy distribution system is essentially ignored. The procedure consists of evaluating several different thermal, chemical, and electrical energy forms. Basically, the evaluation is a technical and economic comparison including capital costs and energy loss costs. Additional qualitative evaluation is accomplished by listing significant features of the various energy modes. Results indicate that hydrogen is superior to all forms of energy transport considered. An Eva-Adam system is intermediate between hydrogen and electricity or hot

water. High-voltage electric overhead transmission and hot water are the most expensive systems. In addition, for the case of a large energy center, all of the pipeline methods of energy transport are superior to electric transmission from the viewpoints of heat rejection and the "getaway" problem.

(CHEMICAL HEAT-PIPE, HYDROGEN, METHANE, ENERGY TRANSPORT)

HP77 21009 LOW COST HIGH PERFORMANCE GENERATOR (LCHPG)

Lieberman, A.R., Osmeyer, W.E., Hammel, T.E., Carpenter, R.T., (Teledyne Energy Systems, Timonium, MD), American Institute of Chemical Engineers, New York, 1976, Eleventh Intersociety Energy Conversion Engineering Conference, V 2
Avail:TAC

Teledyne Energy Systems (TES) has been under contract to U.S. Energy Research and Development Administration (ERDA) since 1973 to develop a low cost, high efficiency radioisotopic thermoelectric generator (LCHPG). The LCHPG technology is based on PU-238 oxide fuel and high performance selenide thermoelectrics under development by the 3M Company. Studies in the search for a safe, low weight, high performnace generator have concluded in a 500 watt(E) LCHPG reference design which yields in excess of 10 percent system efficiency, more than 3 watts(E)/pound and greater safety and lower cost than existing rtgs. A typical LCHPG system has four heat pipe augmented fins, thermoelectric hot and cold junction temperatures of 900°A-C and 125°A-C, respectively, and a radiator temperature of 90°A-C. Power level typically can range from 25 to 500 watts(E) in 25 watt(E) modular increments. Production costs are expected to be about $6000 per watt(E) by 1981. Most recent efforts have concentrated on hardward development and will culminate in 1978 in an electrically heated 100 watt(E) generator (ETG). This technology phase will emphasize development of ETG components, e.g., the selenide thermoelectrics, fibrous insulation, Cu / H °A2O heat pipes and an isolation hot frame for separating the heat source from the converter compartment. Growth potential can be realized by uprating hot junction temperature and improving the gadolinium selenide N-LET / these improvements should yield an ultimate system efficiency of over 13 percent, a specific power in excess of 4 watts(e)/pound and a production cost less than $5000 per watt(E).

(THERMOELECTRIC GENERATOR, RADIOISOTOPES, ECONOMICS, DEVELOPMENT)

HP77 21010 SOLAR COLLECTOR THERMAL POWER SYSTEM: ITS POTENTIAL AND DEVELOPMENT STATUS

Mahefkey, E.T., Jr., (Air Force Systems Command, Wright-Patterson AFB, OH), American Chemical Society, Washington, DC, 1972, 7th Intersociety Energy Conversion Engineering Conference
Avail:TAC

No abstract available

(ENERGY CONVERSION, ENERGY STORAGE, SOLAR CELLS)

II. C. ENERGY CONSERVATION, SOLAR, NUCLEAR, AND OTHER ENERGY SYSTEMS

HP77 22013 EXPECTED FUTURE OF THE HEAT PUMP (THERE'LL BE MORE OF THEM)

Barnett, R.C., Elec. App., V 28:29-30, N1, May 1975
Avail:TAC

No abstract available

(ENERGY CONSERVATION, ECONOMICS, WASTE-HEAT RECOVERY, HEAT-PIPE RECUPERATOR)

HP77 22014 CONSERVATION IN INDUSTRY

Berg, C.A., (Federal Power Commission, Washington, DC), Science, V 184:264-270, N4134, Apr 19, 1974
Avail:TAC

No abstract available

(ENERGY CONSUMPTION, INDUSTRIAL PLANTS, COMPUTERS, ECONOMICS)

HP77 22015 RESEARCH ON FLAT PIPE SOLAR COLLECTORS EMPLOYING THE HEAT PIPE PRINCIPLE FOR HEATING AND COOLING OF BUILDINGS

Bienart, W.B., (Dynatherm Corp., Cockeysville, MD), NSF-7409164, Aug 1974-Aug 1975
Avail:TAC

This project will study the feasibility of modular flat plate collectors employing the heat pipe principle to extract heat from the solar absorber surface and transport this heat to a primary fluid loop (either liquid or gas). The project will concentrate on the heat pipe collector surface and its interface with other module and system components. Existing research data on glazing, absorbing coatings and insulation will be utilized and not further developed in this project. A submodule-size heat pipe solar collector will be designed, constructed and tested to determine the overall thermal impedence of heat pipe solar collector. For this study, solar input will be simulated by electrical resistence strip heaters attached to the collector surface. A part of the submodule studies will be to identify possible failure mechanisms and conduct tests in which the processes leading to failure are accelerated. Based on the preceding studies, a full-scale module will be designed and fabricated and then tested under actual solar radiation. Parametric performance studies and economic analyses will be conducted as part of this program.

(ENERGY CONSERVATION, ECONOMICS, ABSORBER COATINGS)

HP77 22016 DISTRICT HEATING FROM THE NUCLEAR POWER STATION BARSEBAECK IN SWEDEN

Blomqwist, O., Sydsvenska Kraft Ab, Malmoe, Sweden, July 1974, In Swedish
When the oil prices started to rise during the autumn of 1973, a rough estimate calculation showed that the conditions for heat transfer from the nuclear power station Barsebaeck, in Sweden to the cities Malmoe and Lund and perhaps also to Helsingborg and Landskrona are good. In the nuclear power station Barsebaeck the third plant may be used for both heat and power production. This report gives an account of the work being done.

(WASTE HEAT RECOVERY, ECONOMICS, HEAT TRANSFER)

HP77 22017 FEASIBILITY OF A HEAT AND EMISSION LOSS PREVENTION SYSTEM FOR AREA SOURCE FURNACES - Final Report

Brown, R.A., Moyer, C.B., Schreiber, R.J., (Acurex Corp., Mountain View, CA, Aerotherm Div.), Apr 1976
Avail:TAC
The report gives results of a brief study to determine the feasibility of candidate concepts for simultaneous heat and air pollutant recovery from the exhaust of domestic-size furnaces. Among the concepts investigated were improved heat exchanger design, vent dampers and heat pipes, and post-combustion emission control devices such as filters and wet scrubbers.

(FURNACES, WASTE HEAT RECOVERY, POLLUTION CONTROL)

HP77 22018 DOMESTIC BUILDING WITH A TEST SYSTEM FOR THE UTILIZATION OF SOLAR ENERGY

Dietrich, B., (Rheinisch-Westfaelisches Elektrizitaetswerk A.G., Essen, Germany, F.R., Abt. An Wend Ungstechnik), Tech. Eau, Brussels, V 3:237-243, 1976, In German
In Essen, a domestic building was equipped with a testing system for the utilization of solar energy for space heating and warm service water preparation with financial support by the Federal Ministry for Research and Technology. The system is to serve to collect practical experiences about expenses and efficiency of solar energy utilization for the heat supply of a domestic building built in conventional style and well insulated under the meteorological conditions of northern Germany. The flat plate collectors are installed on the southward sloping roof and function according to the heat-pipe-principle. The collector heat is led to the hot water storage in the cellar for service water preparation and heating via heat exchangers and a water circulation. The collectors efficiency can be increased by means of a heat pump, especially at times of little solar radiation. The installed hot-water floor heating ensures a low level of heating temperature. A flexible design of the energy system allows to test several conceptions of storing solar heat and using the additional energy necessary at times of bad weather conditions.

(BUILDINGS, SOLAR SPACE HEATING, THERMAL STORAGE, EQUIPMENT)

HP77 22019 NEW ENERGY CONSERVATION IDEAS FOR EXISTING AND NEW BUILDINGS

Dubin, F.S., (Dubin-Mindell-Bloome Associates, NY), 1975, CONF-750942
Avail:TAC
While the development of new materials and equipment to conserve energy is essential for the long term, even the existing techniques, equipment and systems which could reduce annual energy consumption are not being fully utilized in buildings because of institutional constraints. Many of the same constraints act to deter new developments. Those constraints are identified and new ideas for legislation, education and training, incentives, financing, research, and design methods to remove such constraints are suggested.

New equipment and system concepts are outlined, such as utilization of solar energy, heat pumps, heat pipes, desicant dehumidification, and chilled and hot water storage systems / but it is shown that most of the new ideas are, in fact, innovative use of older technologies which must be reintroduced now. The importance of becoming thoroughly familiar with, and using, innovative systems which are available is stressed, rather than waiting for the development of new products. Examples are presented showing the energy conservation and economic benefits of industrial processes when integrated with building environmental control systems. Some suggestions are included for refrigeration equipment, and glass which changes its characteristics with varying ambient conditions. The use of these new products, which appear to be imminent, will result in lower capital costs, while increasing the potential for greater energy conservation in buildings.

(HEAT PUMPS, HEAT STORAGE, SOLAR HEATING, SPACE HEATING, BUILDINGS)

HP77 22020 PARTICULATES COOL HEAT-RECOVERY UNITS

Edwards, P.L., Energy User News, V 1:18, N2, Oct 11, 1976
Avail:TAC

Problems with heat recovery equipment used in industrial paint drying ovens are widespread. The most serious part of the problem is avoiding build-up of paint particulate matter that renders the heat recovery equipment ineffective. Avoiding the problem altogether can drive the cost of a system up five times, but reducing the problem to an annual maintenance chore is now within the means of major heat recovery equipment manufacturers. In the five years since the development of heat recovery as an adjunct to paint drying ovens, major suppliers have developed detailed application specifications to make the particulate problem manageable before installation. This is accomplished by minimizing the potential for particulate build-up and by insuring ready access to the equipment for ease of removing the paint or cleaning when it becomes necessary.

(ENERGY CONSERVATION, PAINT DRYING OVENS, INDUSTRIAL PLANTS)

HP77 22021 IMPROVEMENTS TO THE COOLING SYSTEM OF A FUSION REACTOR

Farfaletti-Casali, F., Peter, F.G., Gritzmann, P.G., Dec 17, 1975, British Patent 1,418,319/B//
Avail:TAC

An improved cooling system is claimed for fusion reactors having a toroidal or linear configuration and having a Li blanket. In this kind of reactor the plasma cavity is surrounded by an annular chamber containing liquid Li, the main functions of which are to thermalise neutrons and to breed T at a rate greater than its consumption in the fusion process. The blanket zone is surrouned by another annular chamber containing graphite absorber, and by other moderating and shielding zones. Main problems requiring a satisfactory solution are cooling of the blanket and recovery of the T. The cooling system described consists of inner and outer concentric annular chambers, with a rigid wall separating these chambers. The inner chamber contains Li and the outer chamber contains a neutron moderating material such as graphite. A number of heat pipes are radially located in the chambers and pass through the intermediate wall for heat transfer from the inner to the outer chamber, and a cooling medium is provided to transfer heat from the outer chamber. The evaporation zones of the heat pipes are located in the Li in the inner chamber and the condensing zones are located in the moderating material in the outer chamber. The outer chamber is provided with vacuum means to remove the T extracted by the heat pipes from the Li in the inner chamber.

(MODERATORS, HEAT TRANSFER, COOLING SYSTEMS)

HP77 22022 COST-EFFECTIVENESS STUDY OF HEAT PIPE HEAT EXCHANGERS

Lu, D.C., Feldman, K.T., Jr., (Mechanical Engineering Department, Univ. of New Mexico, Albuquerque, NM), ASME Paper 77-WA/HT-5, Winter Annual Meeting, Atlanta, GA, Nov 27-Dec 2, 1977
Avail:TAC

The high conductance of the heat pipe allows it to be used effectively in heat recovery heat exchangers. Such heat pipe heat exchangers may be used as recuperators in heating and ventilating systems and in a variety of process industry heat recovery applications. A research study is being conducted to optimize the performance and possibly reduce the costs of heat pipe heat exchangers. In this paper the initial costs of three types of heat pipe heat exchangers are presented: aluminum-Freon 11 for the temperature range from -23°C to 121°C (-10°F to 250°F), copper-water for 38°C to 232°C (100°F to 450°F), and carbon steel-Dowtherm A for 120°C to 400°C (248°F to 750°F). An optimization computer program for the cost-effectiveness analysis is developed, which takes into consideration the costs for equipment, installation, operation, and maintenance. An optimization example is given for a carbon steel-Dowtherm A heat pipe heat exchanger designed to recover heat from the 8534 m^3/min (28,000 cfm) of 316°C (600°F) flue gas exhausting from the University heating plant boilers.

The results show that the investment in a heat pipe heat exchanger for heat recovery purposes is worthwhile, especially when rising fuel costs are considered.

(HEAT RECOVERY, RECUPERATORS, ECONOMICS, CONSERVATION)

HP77 22023 HEAT RECOVERY SYSTEMS FOR BUILDINGS

Field, A.A., Energy World, V 16:3-5, May 1975
Avail:TAC
No abstract available

(WASTE HEAT, HEAT EXCHANGERS, ENERGY CONSERVATION, THERMAL WHEELS)

HP77 22024 SAVING ENERGY IN PAINT FINISHING

Flitner, F.P., (Devilbiss Co., Toledo, OH), Prod. Finish., Cincinnati, OH, V 40:46-51, N5, Feb 1976
Avail:TAC
An understanding of energy costs and methods for reducing energy use while maintaining the effectiveness of a finishing system is a comparatively new part of a paint finisher's job. The author shows how to calculate the cost of energy, and discusses ways to save energy in such different operations as those using powder coating systems, electrostatic application, as well as in ovens, heat pipes, spray washers and spray guns.

(SURFACE COATING, ECONOMICS, SURFACE FINISHING, ENERGY CONSERVATION)

HP77 22025 HEAT PIPE FIN, A NOVEL DESIGN OF A PLANAR COLLECTOR

Francken, J.C., (Univ., Groningen, Netherlands), International Solar Energy Society, Rockville, MD, 1975, 1975 International Solar Energy Congress and Exposition
Avail:TAC
No abstract available

(SOLAR ENERGY, CONSERVATION)

HP77 22026 SOLAR THERMAL ELECTRIC POWER

Gervais, R.L., Bos, P.B., Astronaut. Aeronaut., V 13:38-45, N11, Nov 1975
Avail:TAC
No abstract available

(FLAT PLATE COLLECTORS, PARABOLIC COLLECTORS, ENERGY STORAGE)

HP77 22027 SOLAR COLLECTORS. FUNDAMENTALS AND OPERATIONAL DEMAND

Goericke, P., (Wehlmann, Essen, Germany, F.R.), Ergebnisse Von Entwicklungsarbeiten Zur Nutzung Der Sonnenenergie, 1976, In German
The characteristics of several ways of constructing collectors are described after a basic explanation of the function of a solar collector.

(CONSTRUCTION, COST, FLAT-PLATE COLLECTORS)

HP77 22028 HEAT PIPES

Grover, G.M., Smith, D.G., (Q-Dot Corp., Dallas, TX), Inst. of Gas Tech., Chicago, IL, 1974
The heat pipe is an evaporation-condensation device which can transfer large quantities of heat with very small temperature differences. A multiplicity of heat pipes arranged as a counterflow heat exchanger between two air streams finds interesting applications in thermal energy recovery. Commercial and industrial installations are described.

(WASTE HEAT, RECOVERY, INDUSTRIAL PLANTS, COMMERCIAL BUILDINGS)

HP77 22029 HEAT PIPES DECREASE ENERGY COSTS. COMPONENTS WITHOUT MAINTENANCE AND WEAR FOR HEAT RECOVERY

Hake, B., Handelsblatt, V 29:101, N23, June 1976, In German

A brief discussion of the possibilities of application for heat pipes to recover heat in industrial heating, air conditioning, and domestic heating.

(WASTE-HEAT, RECOVERY, CONSERVATION)

HP77 22030 GAS AND OIL-FIRED HEAT PIPE WARM AIR FURNACE-EVALUATION OF CONCEPT, PERFORMANCE AND ECONOMICS

Hall, W.B., (Tappan Co., Development Eng. Dept., Cleveland, OH), Apr 1974
Avail:TAC

The program is to determine the design, performance, and economic feasibility of applying a heat pipe heat exchanger in residential warm air furnaces suitable for multi-position installation in duct distribution systems (upflow, downflow or horizontal flow of conditioned air) and pressure firing with oil or gas. Study of heat pipe materials and design configurations are also included.

(HEAT EXCHANGERS, RESIDENTIAL BUILDINGS, MATERIALS, DESIGN)

HP77 22031 APPLICATION OF HEAT PIPE TECHNOLOGY TO APPLIANCES

Hurley, J., Searight, E., Miskolczy, G., Lazaridis, L.J., (Thermo Electron Corp., Waltham, MA), Mar 1971-July 1974
Avail:TAC

This program is directed toward design and development of high efficiency residential and commercial appliances which utilize heat pipe technology to achieve numerous performance advantages over conventional equipment.

(CONSERVATION, RESIDENTIAL-COMMERCIAL, EQUIPMENT)

HP77 22032 FUEL CYCLE OF FUSION REACTORS

Kiyose, R., Tanaka, S., (Univ. of Tokyo), Nenryo Kyokai-Shi, V 54:951-963, N584, 35 refs, Dec 1975, In Japanese with English Abstract

Principles and plant system designs for nuclear fusion power are described. The development status of fuel-cycle processes of fusion reactor, such as fuel injection, separation of tritium from discharged plasma gases, production and recovery of tritium in blanket, is reviewed. Finally, with regard to the safety and environment problems of fusion power reactors, production and release of radioactivity, especially that of tritium, are examined both in normal operation and during accidents.

(PLASMA PRODUCTION, TRITIUM, SAFETY, ENVIRONMENTAL PROTECTION)

HP77 22033 APPLICATION OF HEAT PIPES IN BOREHOLES WHEN DRILLING IN VACUUM AND REDUCED GRAVITATION CONDITIONS

Kopylov, V.E., Kulyabin, G.A., Grechin, E.G., (Tyumen' Ind Inst, USSR), Izv. Vyssh. Uchebn. Zaved., Gorn, Zh., V 5:93-99, 1975, In Russian

It is proposed to use heat pipes to remove heat from drill bits in pumpless drilling in a vacuum. The purpose is to prolong the service life of diamond or hard-alloy bits. Technological capabilities of pipes are considered. Their length is calculated in dependence on the working temperature of the bit, drilling rate and mechanical rock properties in the borehole. Conditions of starting the heat pipe from a frozen state are considered. Application for rock drilling on the moon is mentioned.

(DRILL BITS, DRILLING, LUNAR ROCK, COOLING)

HP77 22034 APPLICATION OF HEAT PIPES TO GROUND STORAGE OF SOLAR ENERGY

Kroliczek, E.J., (B & K Engineering, Inc., Towson, MD), Yuan, S.W., Bloom, A.M., (George Washington University, Washington, DC), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-729
Avail:TAC

A heat pipe concept design for application to residential solar energy storage has been developed. The basic feasibility of the concept has been demonstrated in prototype testing at George Washington University. The design incorporates the simplicity and high efficiency of the heat pipe together with current heat pipe thermal control techniques and an external pump assist for liquid return against gravity. As configured the heat pipe system provides the capability of transferring heat from solar collectors to an energy storage area and points of utilization within a single heat transfer element. All control functions are inherent in the heat pipe construction including automatic shutdown of the solar collector zone when positive net energy flow is not achieved. Pumping power requirements are minimal and needed only during solar input periods. Future designs could utilize solar energy to drive the pump. Finally, the heat pipe

system can be interfaced with any one or combination of household heat transfer mediums including air, hot water or working fluids from air conditioners or heat pumps. This paper describes the concept, the details of a prototype design and the results obtained with a simulated ground storage test system.

(ENERGY STORAGE, HEAT TRANSFER, SOLAR COLLECTORS, RESIDENTIAL HEATING)

HP77 22035 SOLAR ENERGY APPLIED TO COMFORT AND HEAT SERVICES

Kut, D., Heat. Air Cond. J., p. 40-44, Feb 1975
Avail:TAC
Solar air heaters, small solar power plants, solar furnaces, and heat pipes are briefly discussed.

(AIR HEATERS, POWER PLANTS, FURNACES, HEAT ENGINES)

HP77 22036 PROCEDURE FOR THE SUPPLY OF HEAT RECTIFIER SHINGLES OR HEAT PIPES WITH HEAT CARRIERS OF DIFFERENT BOILING TEMPERATURE

Laing, N., Jan 16, 1975, German Patent 2,330,780/A//, In German
Isolating plates with a cavity containing a heat carrier in a vapor or liquid phase and with side walls carrying layers that are highly absorbing or reflecting light of certain wavelength bands are described.

(COLLECTORS, THERMAL INSULATION, HEAT EXCHANGERS)

HP77 22037 HEATING FROM NUCLEAR POWER STATIONS

Muehlhaeuser, H., (Brown, Boveri and Co. Ltd., Baden, Switzerland), Helbling, W., (Sulzer Bros. Ltd., Winterthur, Switzerland), Sulzer Tech. Rev., V 57:157-164, N3, 1975
Avail:TAC
The article points out the technical and economic aspects in the recovery of heat from nuclear power stations for heating purposes. Various plants and configurations are described and the costs of district heating analyzed.

(PROCESS HEAT, ECONOMICS, HEAT RECOVERY, DISTRICT HEATING)

HP77 22038 HVAC AND INDUSTRIAL AIR-TO-AIR ENERGY RECOVERY

Pannkoke, T., Heat., Piping Air Cond., V 48:63-69, N8, Aug 1976
Avail:TAC
Industrial applications of air-to-air energy recovery can make a major impact on energy conservation. The common devices for transferring heat from one air stream to another are the rotary regenerative unit known as the heat wheel / the coil runaround cycle to transfer sensible heat / the desiccant spray runaround cycle to transfer both sensible and latent heat / the heat pipe / and stationary conductive metal heat exchangers. The application and maintenance of recovery systems for both HVAC and industrial installations are discussed. General applications include space heating and/or cooling / recovery of heat from a process to return the heat to the process / recovery of heat from a process to return the heat to another process / recovery of heat from a process to use it for makeup air heating or space heating / recovery of heat used in fume incineration for use in a process / and lowering of process exhaust temperatures to a level compatible with emission control equipment.

(HEAT RECOVERY, WASTE HEAT, CONSERVATION, VENTILATION)

HP77 22039 UNIQUE SOLAR HEAT PIPE SYSTEM FOR SPACE AND WATER HEATING

Rice, F.H., (Fred Rice Productions, Inc., Van Nuys, CA), International Solar Energy Society, Rockville, MD, 1975
No abstract available

(SOLAR COLLECTORS, SPACE HEATING, WATER HEATING)

HP77 22040 METHOD AND EQUIPMENT FOR HEAT RECOVERY OF FURNACES

Schneider, C., Poehlmann, E., Aug 21, 1975, German Patent 2,406,467/A//, In German
A method of heat recovery from furnaces is described in which the flue gases are passed through a stack. In the familiar types of furnaces the flue gases must have a minimum temperature above the dew point of the pollutants they contain to prevent such pollutants from condensing within the stack. In order to recover the thermal energy

contained in the flue gases, a heat exchanger is installed in the flue gas duct upstream of the stack to lower the flue gas temperature below the dew point temperature of the pollutants, in this way allowing the pollutant condensates to be removed from the flue gas duct. The heat exchangers which lend themselves to this application are in particular systems with heat pipes. The heat is best removed by forced venting of the cold side of the heat exchanger. If, as a result of the cooling of the flue gases, the draft in the stack is insufficient, it is advisable to accelerate the flue gases by fans after the cooling stage.

(AIR POLLUTION, FLUE GAS, HEAT EXCHANGERS, VENTILATION)

HP77 22041 CONTRIBUTION TO THE BOILING CURVE OF SODIUM

Schins, H.E.J., (Technol. Div. JRC-Ispra Establ. Ispra, Italy), Atomkernenergie, Germany, V 26:48-52, N1
Avail:TAC

Sodium was preheated to saturation temperatures at pressures of 200, 350 and 500 torr. A test section of normal stainless steel was then heated by means of the conical fitting condenser zone of a heat pipe. Measurements were made of heat transfer flux, Q in w/cm^2, as a function of wall excess temperature above saturation, in natural convection and boiling regimes. These measurements make it possible to select the subbotin natural convection and nucleate boiling curves among other variants proposed in literature. It is empirically demonstrated on water that the minimum film boiling point corresponds to the homogeneous nucleation temperature calculated by the Doring Formula. Assuming that the minimum film boiling point of sodium can be obtained in the same manner, it may be possible to give an approximate boiling curve of sodium for the use in thermal interaction studies.

(HEAT TRANSFER, CONVECTION, BOILING, NUCLEAR REACTOR)

HP77 22042 PROSPECTS OF THE USE OF HEAT PIPES AND POROUS HEAT EXCHANGERS IN NEW TECHNIQUES

Vasiliev, L.L., (Teplo- I Massoobmen Kriogenicheskikh Zhidkostey V Poristykh Teploobmennikakh), Thermal and Mass Exchange of Cryogenic Liquids in Porous Heat Exchangers, Collection of Works, p. 3-23, 1974, In Russian

No abstract available

(HEAT TRANSFER, OPERATION, THERMAL CONTROL)

HP77 22043 DESIGN CONSIDERATIONS ON HIGH-TEMPERATURE REACTORS FOR PROCESS HEAT APPLICATIONS

Schulten, R., Kugeler, K., Kugeler, M., (Kernforschungsanlage Juelich G.M.B.H., F.R. Germany, Inst. Fuer Reaktorentwicklung), 1975
Avail:TAC

The main requirements are listed and a more detailed survey is given concerning the question of intermediate heat exchangers. The potential advantages of cast steel as a material for reactor vessels are explained. The question of power density in the core, which is important for safety, cost, temperatures, fast dose and conversion factor is considered. Furthermore, the reactor outlet temperature and the influence of this parameter on a lot of data is discussed.

(REACTOR VESSELS, CAST STEELS, POWER DENSITY, EVALUATIONS)

HP77 22044 PEBBLE BED HIGH TEMPERATURE REACTOR AS A SOURCE OF NUCLEAR PROCESS HEAT. VOLUME VII. PROCESSES OF NUCLEAR PROCESS HEAT

Schulten, R., Kugeler, K., Kugeler, M., Niessen, H., Hohn, H., Woike, O., Germer, J.H., (Kernforschungsanlage Juelich G.M.B.H., F.R. Germany, Inst. Fuer Reaktorentwicklung), Aug 1974
Avail:TAC

No abstract available

(COAL GASSIFICATION, HYDROGEN, FUEL OIL, IRON ORES)

HP77 22045 RESEARCH APPLIED TO SOLAR THERMAL POWER SYSTEMS. PROGRESS REPORT, JANUARY 1, 1975-AUGUST 31, 1975

Sparrow, E.M., Gupta, B.P., Wehner, G.K., (Minnesota Univ., Minneapolis, MN), (Honeywell, Inc., Minneapolis, MN, Systems and Research Center), NSF/RANN/SE/GI--34871/PR/75/2, Sept 30, 1975
Avail:TAC
No abstract available

(BOILERS, HEAT STORAGE, PARABOLIC REFLECTORS, SOLAR COLLECTORS)

HP77 22046 RESEARCH APPLIED TO SOLAR-THERMAL POWER SYSTEMS

Sparrow, E.M., Eckert, E.R.G., Ramsey, J.W., Schmidt, R.N., (University of Minnesota, Dept. of Mechanical Eng., Honeywell Inc., MN), NSF/RANN/SE/GI-34871, July 1972-July 1975, Sponsored by NSF, RANN, Honeywell Inc.
Avail:TAC
This project undertakes research and development focused on key technology of photothermal conversion for efficient use of solar energy in large-scale production of electricity. The program includes (1) research and development on components of the system, (2) heat transfer studies on system components, (3) systems performance and tradeoff analysis, and (4) design, construction, and demonstration testing of a modular unit of the proposed collection system. The main system components under study are a solar concentrator which focuses solar energy on a heat pipe, a heat pipe with a selective optical coating, a heat transfer loop connecting the heat pipe to a thermal storage unit, and a thermal storage unit which receives thermal energy from the transfer loop and releases it to the power cycle working fluid. Eight study tasks are undertaken (including experimental work on many of them) as follows: (1) solar reflector surface life, (2) solar absorber coating life, (3) gravity-aided long heat pipes, (4) heat transfer and pressure drop in a transfer loop, (5) heat transfer in a central storage facility, (6) heat transfer in a decentralized storage facility, (7) system design, and (8) module demonstration.

(SOLAR COLLECTOR, CONSERVATION, POWER SYSTEMS, HEAT TRANSFER)

II. D. AEROSPACE APPLICATIONS

HP77 23003 COMPARISON OF NUCLEAR SPACE POWER SYSTEMS WITH TURBOELECTRIC AND WITH THERMIONIC CONVERTERS

Blumenberg, J., (Technische Univ., Munich), Kerntechnik, V 18:29-35, N1, 7 refs, Jan 1976, In German and English
Avail:TAC
Future space power systems with high power ratings will work on the basis of fast nuclear reactors, heat pipe radiators and high efficiency power converters. Comparison shows that the formerly held assumption that thermionic systems are superior is valid to only a very limited extent. For the same net electric power ratings, and applying comparable technological standards, the turbo-electric systems are characterized over the entire achievable range of hot side temperatures and net electric power ratings by lower specific masses, lower cold side temperatures and a very much less sensitive dependence of the specific mass on variations of the hot side temperature.

(SPACECRAFT, POWER SUPPLIES, EVALUATIONS, CARNOT CYCLE)

HP77 23004 COMPARATIVE ASSESSMENT OF OUT-OF-CORE NUCLEAR THERMIONIC POWER SYSTEMS

Estabrook, W.C., Koenig, D.R., Prickett, W.Z., (JPL, Pasadena, CA), Nov 15, 1975, N76-14193
The hardware selections available for fabrication of a nuclear electric propulsion stage for planetary exploration were explored. The investigation was centered around a heat-pipe-cooled, fast-spectrum nuclear reactor for an out-of-core power conversion system with sufficient detail for comparison with the in-core system studies completed previously. A survey of competing power conversion systems still indicated that the modular reliability of thermionic converters makes them the desirable choice to provide the 240-kWE end-of-life power for at least 20,000 full power hours. The electrical energy will be used to operate a number of mercury ion bombardment thrusters with a specific impulse in the range of about 4,000-5,000 seconds.

(ION PROPULSION, SPACE PROPULSION, HARDWARE)

HP77 23005 THERMAL CONTROL OF THE INTERNATIONAL ULTRAVIOLET EXPLORER

Skladany, J.T., Seivold, A.L., (NASA Goddard Space Flight Center, Greenbelt, MD), Am. Soc. Mech. Eng., Paper 76-ENAS-38, July 12, 1976

The International Ultraviolet Explorer (IUE) is a large astronomical observatory scheduled to be placed in a three-axis stabilized synchronous orbit in the fourth quarter of 1977. The thermal control system consists of multilayer insulation, ammonia-filled grooved heat pipes, bimetallic actuated louvers, and assorted commandable heaters. The spacecraft must operate over a 135-deg solar aspect range and must be able to survive an 85-min.-zero power eclipse. It has a design lifetime of three years. To verify the thermal design, an engineering test unit (ETU) was subjected to a thermal balance test in the solar environment simulator (SES) at the Goddard Space Flight Center (GSFC). Heater skins were utilized to simulate four solar aspect angles, and various internal power settings were used to simulate different operational cases. Temperatures obtained corresponded within 5°C of predicted values, thus verifying the thermal analytical model. In addition, two 85-min.-eclipse periods were successfully completed verifying that the thermal design of the IUE was adequate for this mission requirement.

(SPACE-CRAFT, POWER SUPPLIES, THERMAL CONTROL, SOLAR HEATING)

HP77 23006 NEUTRON RADIOGRAPHY WITH A VAN DE GRAAFF ACCELERATOR FOR AEROSPACE APPLICATIONS

Swanson, F.R., Kuehne, F.J., (Grumman Aerospace Corp., Bethpage, NY), Am. Soc. Test. Mater., Spec. Tech. Publ., V 586:158-167, 1976

The objective of this effort was to develop a thermal neutron radiography capability based on a 3-mev Van De Graaff research accelerator, and to apply it to company-related aerospace inspection problems. The research conducted for determining an efficient system design, its final design features, and radiography beam specifications are explained. An example of its use in providing inspection information for the design of a space vehicle heat pipe system is presented.

(NEUTRON SOURCES, SPACECRAFT, INSPECTION)

HP77 23007 LOW COST HIGH PERFORMANCE GENERATOR TECHNOLOGY PROGRAM. VOLUME 5. HEAT PIPE TOPICAL

(Teledyne Energy Systems, Timonium, MD), July 1975, NRA-3075-4
Avail:TAC

Research progress towards the development of a heat pipe for use in the low cost high performance thermoelectric generator program is reported for the period May 15, 1975 through June 1975.

(SPACECRAFT, POWER SUPPLIES, THERMOELECTRICS, RADIOISOTOPES)

II. E. ELECTRICAL AND ELECTRONIC APPLICATIONS

HP77 24002 TRACTION-MOUNTED STATIC CONVERTERS USING HEAT PIPES FOR COOLING

Birnbreier, H., Heidtmann, U., Klein, E., (Brown Boveri, Heidelberg, Germany), BBC Nachr., Germany, V 57:798-202, N4
Avail:TAC

A traction-mounted static converter with direct air-cooling, heat pipes to dissipate the power loss in the semiconductor devices is described. The use of these heat-sinks resulted in the design of a very compact device.

(HEAT SINKS, HEAT DISSIPATION, SEMICONDUCTORS)

HP77 24003 HEAT PIPE COPPER VAPOR LASER. FINAL TECHNICAL REPORT, 1 FEB 1973-30 JUNE 1974

Chimenti, R.J.L., (Exxon Research and Engineering Co., Linden, NJ, Government Research Lab.), Nov 1974, AD/A--005004
Avail:TAC

The program objective was the development of a copper vapor laser in which the copper was contained within a heat pipe and whose vapor density could be controlled by an inert gas. Successful operation of a heat pipe with graphite and tungsten as the materials of construction was obtained to temperatures of 2100°C. Both helium and argon were used for the control of the copper vapor pressure. The second aspect of the program was the development of a discharge configuration capable of the production of high current, short risetime excitation in the vapor and compatible with the heat pipe structure.

Pulse generators were developed which were integral with the laser structure and had variable pulse repetition rates from one to 10,000 pulses per second. In the third part of the program investigation of laser action obtained in the heat pipe was carried out. Laser action at both 5106 and 5782 $A#M was successfully demonstrated at temperatures between 1500 and 1900°C. Multiple laser pulses resulting from a single excitation pulse have been observed at temperatures above 1700°C with pulse widths less than 2.5 NS (bandwidth limited).

(GAS-LASERS, ARGON, COPPER, HELIUM, TUNGSTEN, ELECTRIC DISCHARGE)

HP77 24004 COOLING ELECTRONICS. I

Dalley, M.J., (Intertechnique Ltd., Wembley, England), Eng. Mater. and Des. (GB), V 18: 29-30, N9

The use of heat sinks with heat pipes in eliminating the problem of local hot spots is discussed. Methods of monitoring air temperature are discussed. Methods of monitoring air flow using a thermal air flow switch and the electronic sensor are outlined with developments in the field of temperature sensing discussed.

(HEAT SINKS, TEMPERATURE MEASUREMENT, FLOW MEASUREMENT FORCED FLOW)

HP77 24005 VAPOUR PHASE EPITAXIAL GROWTH OF Ga-As FOR MULTIPLE APPLICATIONS

Hollan, L., Bok, J., (Labs. D'Electronique Et De Phys. Appliquee, Limeil-Brevannes, France), Gallium Arsenide and Related Compounds, Deauville, France, 1974, A75-54978
Avail:TAC

An improved Ga-$AsCl_3$-H_2 VPE method for growing multi-layer structures including N- layers ($N > 10^{14} cm^{-3}$) is described. The advantages of the heat pipe furnace are discussed. The influence of large variations of the $AsCl_3$ molar fraction on the doping level and the growth rate are considered under different growth conditions; allowing good control of the doping level between $5*10^{12}$ and $2*10^{16} cm^{-3}$. This process, with a sulphur doping source, allows the growth of the multilayer structure for millimetre Gunn diodes, nuclear detectors, Gunn amplifiers (TEA) and FET.

(HEAT-PIPE FURNACE, SEMICONDUCTORS, TRANSISTORS, GROWTH)

HP77 24006 HEAT SINKING FOR SEMICONDUCTORS

Houslip, N., New Electron., (GB), V 9:27, 30, N12
Avail:TAC

This article reviews various types of heat sinks and their applications and discusses small 'fan' tops, regainer types, beryllium oxide, PCB mounted types, extruded heat sinks, liquid cooling, fan cooling, heat pipes, as well as a new metal cored PCB.

(COOLING, SEMICONDUCTORS, REVIEW)

HP77 24007 HEAT REJECTION SYSTEMS FOR ELECTROCHEMICAL EQUIPMENT

Kaufmann, J.J., Perreault, W., (NASA, Marshall Space Flight Center, Electronics and Control Lab., Marshall Space Flight Center, AL), NASA-909-51-02 (FY73), NASA-909-55-02 (FY74), NASA-909-55-02 (FY75), July 1972-Dec 1976, Sponsored by Office of Manned Space Flight
Avail:TAC

The objective of this project is to perform basic R&D tasks related to optimization of heat rejection systems using heat pipes operating between 10°C and 100°C for alkaline-hydrogen-oxygen fuel cells, batteries and other astrionic packages. The basic technology for heat pipes of the type required already exists. Additional development is required to resolve operational problems such as cold startup, G-force effect and restart. Specific development is required to assure that heat pipe systems can be applied in fuel cell stacks, batteries, and small astrionics packages. For example, in concentrated heat applications such as inverters, it is important to remove generated heat from printed wiring boards to the housing. Technology is needed especially to conduct heat across the interface between a "slide-in" printed wiring board and the housing. Thermal analyses will be conducted to evaluate possible use of heat pipes as a passive thermal control device for the tug fuel cell, internal portion of a battery housing to housing interface, and printed-wiring-boards-to-housing for astrionics. Should the heat pipe approach prove to be unacceptable, alternate methods will be considered. Tests will be conducted on the various candidate applications to verify the analyses and acceptability of the concept.

(FUEL CELLS, BATTERIES, HEAT TRANSFER, HEAT REJECTION)

HP77 24008 PROBLEMS OF HEAT DISSIPATION IN ELECTRONICS. II

Kilgenstein, O., (Fachhschschule, Nurnberg, Germany), Elektron. Ind., Germany, V 6: 196-197, N10
Avail:TAC

The practical methods of obtaining temperature reduction in electronics are described. Diagrams and curves of deltat vs. dissipated power in heat sinks and R_{th} vs. length of copperclad wings of printed boards are provided and a brief description of heat pipes is included.

(HEAT SINKS, SEMICONDUCTORS, CIRCUIT BOARDS, POWER DISSIPATION)

HP77 24009 CLOSED EVAPORATIVE COOLING OF ROTATING ELECTRICAL MACHINES

Kukharskii, M.P., Inzh.-Fiz. Zh., USSR, V 27:446-456, N3, J. Eng. Phys. Jephal., V 27:1090-1096, N3, Sept 1974
Avail:TAC

The elements of a theory for centrifugo-axial heat pipes are described concurrently with a calorimetric device for experimental investigation. Experimental data is presented to confirm the fundamental correctness of the initial theoretical hypotheses.

(HEAT TRANSFER, INTEGRAL COOLING SYSTEM, EXPERIMENTAL ANALYSIS)

HP77 24010 A TWO-LEVEL, HIGH-POWER, AIR-COOLED TRAVELING-WAVE TUBE FOR COMMUNICATION SYSTEMS

Leborgne, R.H., (Electron Dynamics Div., Hughes Aircraft Co., Torrance, CA), 1975 International Electron Devices Meeting, Technical Digest, Washington, DC, Dec 1-3, 1975
Avail:TAC

A two-level 600/1200 watt cW, x-band, coupled cavity traveling-wave tube with low distortion characteristics and air cooling enhanced by the use of heat pipes is described. This lightweight tube developed for military communication ground terminals is PPM focused and incorporates heat pipes on the RF circuit to uniformly distribute the relatively high thermal loads insuring reliable air cooling. The tube provides either 600 or 1200 watts of saturated cW output power over the frequency band 7.9 to 8.4 GHZ. With two levels of saturation achieved by varying the voltage on an isolated anode, the effective perveance of the electron gun is increased and gain variations of less than 1.2 DB have been achieved across the 500 MHZ band.

(TELECOMMUNICATION, THERMAL LOADS, HEAT TRANSFER, EQUIPMENT COOLING)

HP77 24011 NEW DEVELOPMENTS IN COOLING TECHNIQUES

Markstein, H.W., Electron. Packag. and Prod., V 16:36-38, 40, 44, N5
Avail:TAC

Modern electronic equipment consumes less power than previously required by its predecessors for the same functions. Modern electronic systems have also been compressed in size and incorporates more functional capability. Thermal management problems have not diminished and may be even greater in today's system's design. Various techniques, such as simple heat-sink clips to heat-pipe heat exchangers, have been employed to remove heat from electronic equipment.

(HEAT SINKS, HEAT EXCHANGERS, ELECTRONIC EQUIPMENT)

HP77 24012 PILE TYPE BATTERY INTEGRATED THERMAL CONTROL

Marsh, R.A., Mortel, D.P., (U.S. Dept. of Defense, Aero Propulsion Lab., Dayton, OH), July 1974-June 1975, Sponsored by U.S. Dept. of Defense, Air Force, AF-DF456770
Avail:TAC

Analysis and experimental evaluation of cooled and uncooled 50v, 1620 amp-sec pile battery, to demonstrate enhanced cycle time, extended on time (from 30 sec discharge to 2 min discharge), and cooling system integration ease. To evaluate power pulse transients. Design, fabricate and integrate heat pipes into prototype silver-zinc, pile type batteries. Cooled battery performance will be compared with uncooled to see if technical objectives can be demonstrated.

(BATTERIES, COOLING SYSTEMS, STORAGE CELLS, SILVER-ZINC)

HP77 24013 MODULAR HEAT SINK

Parsapour, H., (IBM, Armonk, NY), IBM Tech. Disclosure Bull., V 17:3313, N11
Avail:TAC

Much improved heat conductivity by thermal contact between the heat sink and module were obtained by using a heat pipe in the form of a bellows, flexible in a longitudinal direction. Thermal grease was used between the heat pipe and module to keep the thermal resistance low at the evaporator end.

(BELLOWS HEAT-PIPE, HEAT SINK, THERMAL RESISTANCE, CONDUCTIVITY)

HP77 24014 HEAT REMOVAL SYSTEM FOR ILLUMINATION DEVICE

Paterson, R.L., (IBM, Armonk, NY), IBM Tech. Disclosure Bull., V 17:2683, N9
Avail:TAC

A system is employed adjacent to the illumination device of a duplicating machine to remove excessive heat from the document area. In its simplest form, the heat pipe consists of a vacuum chamber with a capillary structure (wick), saturated with some volatile fluid.

(PHOTO-DUPLICATION, LIGHT SOURCE, HEAT REMOVAL)

HP77 24015 THE HEAT PIPE IN ELECTRONICS

Ratcliff, G., Electron, (GB), p. 22-24, N73
Avail:TAC

A heat pipe consisting of an evacuated and sealed boiling-condensing system, with either thermosyphon or capillary 'wick'-heat pipe return to the condensed working fluid from the condenser to the evaporator. By utilising the latent heat of vaporisation of the circulating working fluid, large quantities of thermal energy can be transferred long distances with minimal driving force (temperature difference between evaporator and condenser sections) in an entirely passive mode.

(SEMICONDUCTORS, HEAT SINKS, HEAT TRANSFER)

III. HEAT PIPE THEORY

III. A. GENERAL THEORY

HP77 30012 CONTROLLABILITY ANALYSIS FOR PASSIVELY AND ACTIVELY CONTROLLED HEAT PIPES

Lehtinen, A.M., (Rockwell International, Downey, CA), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-776
Avail:TAC

An analytical technique was developed for steady state and pseudo-transient control analysis of variable conductance heat pipes (VCHP) and feedback controlled heat pipes (FCHP). The approach uses a modified vapor temperature profile and a simple 5-node thermal network. This approach differs from past techniques in that it accounts for gas blockage of the adiabatic section and the set point temperature is referenced to the control point node rather than the vapor node. In FCHP systems, the gas inventory is determined at a design set point temperature and held constant for analysis of varying controller set point temperatures. The pseudo-transient analysis integrates the reservoir response time equations with the steady state control equations. The most significant findings were that reservoir volume increases due to controller set point, response time, and reservoir temperature limitations; and the existence of minimum and maximum controller set point temperatures when reservoir temperature limitations exist.

(VCHP, FCHP, THERMAL NETWORK, ANALYTICAL TECHNIQUE)

HP77 30013 TRANSPORT PHENOMENA IN HEAT PIPES

Tien, C.L., Davis, L.R., Wilson, R.E., (Univ. California, Berkeley, CA), Proceedings of the 1974 Heat Transfer and Fluid Mechanics Institute, Corvallis, OR, A75-15255
Avail:TAC

The authors purpose is to provide orientation for those interested in heat transfer and fluid mechanics but unfamiliar with this emerging technology, and, to present a critical appraisal of the current status of a few selected fundamental transport problems in heat pipes.

(HEAT TRANSFER, FLUID MECHANICS, OVERVIEW)

III. B. HEAT TRANSFER

HP77 31007 THE MULTISTAGE HEAT PIPE RADIATOR - AN ADVANCEMENT IN PASSIVE COOLING TECHNOLOGY

Wilson, D.E., Wright, J.P., (Rockwell International, Downey, CA), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-760
Avail:TAC

Mathematical models were developed for one-, two-, and three-stage radiator systems to determine optimum stage areas and system performance as a function of such parameters as insulation effectiveness, cold stage temperature, and heat load to the cold and intermediate stages. This study shows that multi-stage radiator systems can be optimized on the basis of weight or projected area, and that cold stage temperatures as low as 15°K are theoretically possible with present technology levels for insulation emittance. Optimum radiator geometry for a given temperature was found to be independent of the magnitude of the heat load; hence, the results can be scaled up or down for any size system. The addition of a heat load to the intermediate stage did not significantly affect cold stage heat rejection for heat loads up to 10 times the cold stage load. This is significant for sensor systems requiring additional cooling at intermediate temperatures. For the baseline design, analyses were performed to determine optimum radiator fin geometry and heat pipe spacing as a function of temperature, material properties, and heat pipe weight. In addition, a ground test system was designed for the baseline design with heat rejection requirements of 10 mW at 35°K on the cold stage and 100 mW at the second stage.

(MATHEMATICAL MODEL, FIN GEOMETRY, SPACING, WEIGHT)

HP77 31008 SOME PROBLEMS OF THE HEAT AND MASS TRANSFER THEORY. I

Luikov, A.V., (Heat and Mass Transfer Inst. Minsk, Belorussian), Lett. Heat and Mass Transfer (GB), V 1:147-58, N2, A75-64191
Avail:TAC

Deals with the theory of heat and mass transfer: heat transfer by conduction in materials with memory; heat conduction in bodies with phase conversions when transfer coefficients and thermodynamic properties vary spasmodically; heat and mass transfer in capillary-porous bodies and wick materials of heat pipes.

(PHASE CONVERSION, THERMODYNAMICS, WICK, MATERIALS)

HP77 31009 REFLUX CONDENSER - HEAT PIPE

Rhodes, R.A., Patil, A.S., (U.S. Dept. of Defense, Army Mobility Equipment R&D Center, Fort Belvoir, VA), July 1973-June 1974, Sponsored by U.S. Dept. of Defense, Army
Avail:TAC

This investigation is intended to disclose the operating and design parameters of heat pipe technology and to discover ideal operating fluids, materials, dimensions and controls applicable to Mobile Army Environmental Control Systems and other heat transfer uses. Conduct a mathematical analysis of the fluid and thermal dynamics of each process in the heat pipe cycle. Develop computer program which will determine coefficient of performance for any media in any pipe configuration over a range of temperatures for a desired capacity. Candidate operating fluids possessing properties of high latent heat, low density and viscosity, high surfact tension and thermal stability will be tested in various heat pipe configurations to build-up and transient response. Methods of control will be investigated.

(VISCOSITY, DENSITY, SURFACE TENSION, COMPUTER PROGRAM)

HP77 31010 A ZERO G VARIABLE CONDUCTANCE HEAT PIPE USING BUBBLE PUMP INJECTION

Roberts, C.C., Jr., (Engineering Consultant, Packer Engineering Associates, Naperville, IL), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-752
Avail:TAC

Methods for varying the thermal conductance of a heat pipe include liquid flow control, vapor flow control and condenser blockage. A new way to vary heat pipe thermal conductance has been achieved by using a bubble pump to control return liquid flow. This has been proven in a 1-g environment. In an attempt to apply this concept to the 0-g environment, various heat pipe fluid models were tested on a 0-g simulator. The design appears feasible over a range of Bond Numbers from 0-16.

(THERMAL CONDUCTANCE, FLOW CONTROL, BOND NUMBER)

HP77 31011 THE EFFECT OF THE LIQUID-SOLID SYSTEM PROPERTIES ON THE INTERLINE HEAT TRANSFER COEFFICIENT

Wayner, P.C., Jr., (Dept. of Chemical and Environmental Engineering, Rensselaer Polytechnic Institute, Troy, NY), Aug 1977
Avail:TAC

A theoretical procedure to determine the heat transfer characteristics of the interline region of an evaporating meniscus using the macroscopic optical and thermophysical properties of the system is outlined. The analysis is based on the premise that the interline transport processes are controlled by the London-van der Waals forces between condensed phases (solid and liquid). The procedure is used to compare the relative size of the interline heat sink of various systems using a constant heat flux model. This solution demonstrates the importance of the interline heat flow number, $\bar{A}\, h_{fg}\, \nu^{-1}$, which is evaluated for various systems. The heat transfer characteristics of the decane-steel system are numerically compared with those of the carbon tetrachloride-quartz system. In order to evaluate the theoretical models and obtain direction for their refinement, the length of the interline region and the stability of the meniscus should be experimentally determined as a function of the heat flux and the interline heat flow number.

(EVAPORATING MENISCUS, INTERLINE TRANSPORT, LONDON-VAN DER WAALS FORCE)

HP77 31012 TRANSFER PROCESSES IN AN EVAPORATING MENISCUS AND ADSORBED THIN FILM

Wayner, P.C., Jr., (Dept. of Chemistry, Dept. of Environmental Eng., Rensselaer Polytechnic Institute, Troy, NY), Aug 1971-Nov 1976, National Science Foundation
Avail:TAC

The transport processes occurring in evaporating meniscus and adsorbed thin film are being studied experimentally and theoretically. This basic research study is concerned with understanding the processes of boiling, dropwise condensation, transpiration cooling and the rewetting of a hot spot. Evaporation from porous media is also being studied experimentally and theoretically. The research is directed toward the understanding and design of "heat pipe" type heat exchanges.

(HEAT EXCHANGERS, EVAPORATION, THIN FILMS, POROUS MEDIA)

III. C. FLUID FLOW

HP77 32006 EXCESS LIQUID IN HEAT-PIPE VAPOR SPACES

Eninger, E., Edwards, D.K., (TRW Defense and Space Systems Group, Redondo Beach, CA), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-748
Avail:TAC

A mathematical model is developed of excess liquid in heat pipes that is used to calculate the parameters governing the axial flow of liquid in fillets and puddles that form in vapor spaces. In an acceleration field, the hydrostatic pressure variation is taken into account, which results in noncircular meniscus shapes. The two specific vapor-space geometries considered are circular and the "Dee-shape" that is formed by a slab wick in a circular tube. Also presented are theoretical and experimental results for the conditions under which liquid slugs form at the ends of the vapor spaces. These results also apply to the priming of arteries.

(MATHEMATICAL MODEL, AXIAL FLOW, MENISCUS SHAPES, PRIMING)

HP77 32007 INVESTIGATION OF COUNTERFLOW SHEAR EFFECTS IN HEAT PIPES

Feldman, K.T., Jr., Thupvongsa, C., (Mechanical Engineering Department, The University of New Mexico, Albuquerque, NM), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-749
Avail:TAC

In this study the entrainment-shear performance limit which occurs in heat pipes was investigated and explained. In the existing heat pipe literature the entrainment heat flux limit is defined as the condition where the Weber number is greater than or equal to one. In this analysis, the critical value for the entrainment Weber number is found to be $2\pi \leq We \leq 3\pi$. Perhaps more important to the heat pipe designer than the entrainment performance limit is the prediction of the performance degradation due to vapor-liquid shearing stress which is also described. Preliminary qualitative experiments were conducted to observe the shear stress wave formation phenomena. The equations presented in this analysis may be used to predict and minimize the vapor-liquid shear stress performance effects that occur in axial groove and puddle flow artery heat pipes.

(ENTRAINMENT, SHEAR, HEAT FLUX, AXIAL GROOVE, PUDDLE FLOW)

HP77 32008 PERFORMANCE OF GRAVITY-ASSISTED HEAT PIPES OPERATED AT SMALL TILT ANGLES

Kamotani, Y., (Department of Mechanical and Aerospace Engineering, Case Western Reserve University, Cleveland, OH), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-750
Avail:TAC

Performance of a gravity-assisted heat pipe operated at small tilt angles is investigated theoretically including the effect of vapor-shear. The vaopr-shear creates a back-flow region at the surface of the puddle, and thereby degrades the pipe performance. A formula is obtained for the liquid pressure drop which accounts for the vapor shear effect. The performance of the pipe is strongly influenced by the fluid inventory and the tilt. It is found that if the fluid charge exceeds a certain amount, the pipe operation becomes unstable at a relatively small heat transport.

(FLUID INVENTORY, VAPOR SHEAR, LIQUID PRESSURE DROP)

HP77 32009 INVESTIGATION OF THE PROCESSES OF PHASE HYDRODYNAMICS IN CORELESS HEAT PIPES USING WATER

Semena, M.G., Zhuk, S.K., (Teploenergetika, Moscow), V 3:82-84, Mar 1976, In Russian

Results are presented of an experimental investigation of phase interaction in coreless heat pipes. Relations of dependence of an increase in the thickness of the condensate film on an increase in steam flow velocity, as well as of changes in the tangenitial stress at the phase interface on an increase in the intensity of heat removal, are given. The onset of carrying away of the condensate is determined and the process of its accumulation in the condensation zone is shown.

(CONDENSATES, FILMS, FLUID FLOW, PHASE INTERFACE, HEAT REMOVAL)

IV. DESIGN, DEVELOPMENT AND FABRICATION

IV. A. GENERAL

HP77 40009 HEAT PIPE: A NEW CANDIDATE FOR POWER PLANT HEAT RECOVERY

(Electr. Light Power, Boston, MA), V 54:18-19, N3, Mar 15, 1976
Avail:TAC

The design, operation, performance, and limitations of finned heat exchangers made of several hundred heat pipes are discussed. Possible uses of these units to recover waste heat in power plants are described and include reheating of exhaust gas from sulfur scrubbers and heat recovery from gas turbine exhaust gas to preheat incoming air, thereby improving the efficiency of the turbine and reducing thermal pollution effects.

(WASTE HEAT, SCRUBBERS, EXHAUST GAS, THERMAL POLLUTION)

HP77 40010 HEAT PIPE HEAT EXCHANGER DESIGN AND OPTIMIZATION

Feldman, K.T., Lu, D.C., (Dept. of Mech. Engrg. and Bureau of Engrg. Research, Univ. of New Mexico, Albuquerque, NM), NSF-374-1, July 1977, Final Report No. ME-81(77)
Avail:TAC

Heat pipe heat exchangers are competitive in heat recovery applications because they have many advantages over other conventional heat exchangers such as rotary regenerators and runaround heat exchangers. In order to design a heat pipe heat exchanger with optimum cost-effectiveness and best overall performance, an optimization model to minimize the total cost is developed. The computed results of an example using this model are presented. These lead to the conclusion that the total long-range fuel saving is very high. The Colburn modulus j and friction factor f are presented in terms of the Reynolds number for staggered finned-tube banks with segmented helical circular fins, solid helical circular fins, and corrugated plate fins. Three types of heat pipes for heat exchanger design are investigated: carbon steel-Dowtherm A heat pipes, copper-water heat pipes, and aluminum-Freon 11 heat pipes. A simple method using the thermal resistances approach is described to analyze the performance of heat pipe heat exchangers. The influences of various parameters on effectiveness and pressure drop of the heat exchanger depends on the maximum axial heat transfer rate of each heat pipe in the exchanger. Taking the vapor shear effect on the liquid-vapor interface into account, a thread-puddle-artery heat pipe has a much smaller axial heat transfer rate than would be expected with working fluids such as water or Dowtherm A. One drawback of heat pipe heat exchangers is their relatively high initial cost. Further studies to improve their performance and to cut down their expense are recommended.

(COST EFFECTIVENESS, OPTIMIZED MODEL, THREAD-PUDDLE-ARTERY HEAT-PIPE)

HP77 40011 RE-ENTRANT GROOVE HEAT PIPE

Harwell, W., (Grumman Aerospace Corporation, Bethpage, NY), Kaufman, W.B., Tower, L.K., (NASA, Lewis Research Center, Cleveland, OH), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-773
Avail:TAC

This paper describes theoretical and experimentally verified heat pipe characteristics of an axially grooved aluminum extrusion with a re-entrant groove profile. The extrusion is 13 mm diameter with 20 axial grooves, each groove consisting of a nominal .8 mm diameter channel with a .2 mm wide passageway connecting the channel to the hollow core. A computer program was written to compute the zero gravity heat transport capability of the extrusion. A heat pipe was fabricated and its performance characteristics measured. The characteristics of the pipe with ammonia at 20°C are: zero gravity pumping limit 143 w-meters; static wicking height 21.5 mm; evaporator and condenser coefficients 7300 and 20,500 watt/m^2°C, respectively.

(ALUMINUM EXTRUSION, AMMONIA, COMPUTER PROGRAM)

HP77 40012 HEAT PIPE AND METHOD OF PRODUCTION OF A HEAT PIPE

Kemp, R.S., May 22, 1975, German Patent 2,453,956/A//, In German

The heat pipe consists of a copper pipe in which a capillary network or wick of heat-conducting material is arranged in direct contact with the pipe along its whole length. Furthermore, the interior space of the tube contains an evaporable liquid for pipe transfer. If water is used, the capillary network consists of, e.g., a phosphorus band network. To avoid contamination of the interior of the heat pipe during sealing, its ends are closed by mechanical deformation so that an arched or plane surface is obtained which is in direct contact with the network. After evacuation of the interior

space, the remaining opening is closed with a tapered pin. The ratio wall thickness/ tube diameter is between 0.01 and 0.6.

(WICK, HEAT TRANSFER, COPPER, PHOSPHORUS)

HP77 40013 HEAT PIPES. I. DESIGN CONSIDERATIONS AND MANUFACTURE

Patrickson, P., (Solek Ltd. Sevenoaks, England), Electr. Equip. (GB), V 14:53, 55-56, N10
Avail:TAC

The concept of heat pipes has been with us for some time now. At first thought of as a 'toy', the heat pipe has now become firmly established. It is accepted as a valuable aid to temperature control. What it is and how it is made, this article gives some insight into solving these problems.

(WICK, FABRICATION, MATERIALS)

HP77 40014 HEAT PIPES. II. ENGINEERING APPLICATIONS

Patrickson, P., Electr. Equip. (GB), V 14:41, 43, N12
Avail:TAC

The first part of this article, (IBID. N10, p. 53, 1975) design considerations and manufacturing techniques are discussed. The second part deals with applications - of just as much relevance to the design engineer. It is emphasized that specific details are very much dependent upon the precise parameters prevailing, and for this reason the heat pipe manufacturer should be consulted during design stages with a view to optimizing the chosen heat pipe system.

(SYSTEM, FABRICATION, COOLING)

HP77 40015 IMPROVED HEAT CONDUCTION PIPE

Ratcliff, G., Kemp, R.T., Feb 27, 1975, German Patent 2,430,880/A//, In German
Avail:TAC

A heat transmission pipe is described, in which the conductivity is much larger in one direction than in the other.

(DESIGN, HEAT TRANSFER, CONVECTION)

HP77 40016 FLEXIBLE CRYOGENIC HEAT PIPE DEVELOPMENT PROGRAM - Final Report

Wright, J.P., (Rockwell International, Space Division, Downey, CA), NASA CR 152027, July 1977, NAS2-8830
Avail:TAC

This report summarizes the results of Contract NAS2-8830, "Development of a Flexible Cryogenic Heat Pipe Program." The program was initiated in July 1975 and was completed in July 1977. The program was an analytical and experimental technology development effort to develop the technology and experience necessary for successful application of high performance flexible cryogenic heat pipes. Two pipes were designed and fabricated for testing and evaluation. One was designed for operation in the 100-200 K temperature range with maximum heat transport as a primary design goal; the other was designed for operation in the 15-100 K temperature range with maximum flexibility as a design goal.

(CONTAINER, WICK, METHANE, ETHANE, NITROGEN, OXYGEN)

IV. B. WICKS

HP77 41013 LOW TEMPERATURE HEAT PIPE STUDIES

Leffer, T.C.B., (Wayne State University, College of Eng., Energy Center, Detroit, MI), August 1974 - Continuing/Research, Wayne State University/National Science Foundation
Avail:TAC

The purpose of this research is to study the phenomenon of thin-film evaporation in the wicks of low-temperature heat pipes. With properly designed wicks, extremely high liquid-to-vapor conversion rates can be obtained in the evaporator section. After development of a high intensity heat source, experimental measurements on various wick designs will be used to construct a mathematical model of the operation.

(WICK, THIN FILMS, EVAPORATION, MATHEMATICAL MODEL)

HP77 41014 A STRUCTURED SURFACE FOR HIGH PERFORMANCE EVAPORATIVE HEAT TRANSFER

Saaski, E.W., Hamasaki, R.H., (Sigma Research, Inc., Richland, WA), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-778
Avail:TAC

An evaporative surface is described for heat pipes and other two-phase heat transfer applications that consists of a hybrid composition of V-grooves and capillary wicking. Characteristics of the surface include both a high heat transfer coefficient and high heat flux capability relative to conventional open-faced screw thread surfaces. With a groove density of 12.6 cm^{-1} and ammonia working fluid, heat transfer coefficients in the range of 1 to 2 W/cm^2K have been measured, along with maximum heat flux densities in excess of 20 W/cm^2. A peak heat transfer coefficient in excess of 2.3 W/cm^2K at 20 W/cm^2 was measured with a 37.8 cm^{-1} hybrid surface.

(V-GROOVES, CAPILLARY WICK, AMMONIA, HEAT FLUX)

IV. C. MATERIALS

HP77 42005 WETTING AND SURFACE PROPERTIES OF REFRIGERANTS TO BE USED IN HEAT PIPES

Reale, F., Cannaviello, M., (Instituto di Fisica Tecnica, University of Napoli, Italy)
Avail:TAC

A simple and yet accurate method of measuring surface properties of fluids is presented. Surface tension and contact angles are investigated for some organic coolants, R-11, 12, 21, 22, 114 and 502.

(CONTACT ANGLE, SURFACE TENSION, ORGANIC COOLANTS)

HP77 42006 TWO-PHASE WORKING FLUIDS FOR THE TEMPERATURE RANGE 100-350°C

Saaski, E.W., (Sigma Research, Inc., Richland, WA), Tower, L., (NASA Lewis Research Center, Cleveland, OH), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-753
Avail:TAC

The decomposition and corrosion of two-phase heat transfer liquids and metal envelopes have been investigated on the basis of molecular bond strengths and chemical thermodynamics. Potentially stable heat transfer fluids for the temperature range 100°C to 350°C have been identified, and reflux heat pipe tests initiated with 10 fluids and carbon steel and aluminum envelopes to experimentally establish corrosion behavior and noncondensable gas generation rates.

(CARBON STEEL, ALUMINUM, GAS GENERATION, CORROSION)

V. TESTING AND OPERATION

HP77 50024 THE HEAT PIPE HEAT BRIDGE AND THERMAL CONTROLLER

Arcella, F.G., (Westinghouse Research and Development Center, Pittsburgh, PA), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-751
Avail:TAC

A novel heat pipe heat bridge is described. A non-condensible gas pocket is placed in a heat pipe between axially opposed heat sources. The gas pocket, driven by each heat source, assumes a position in the common condenser zone that is indicative of the strength of each heat source. The resulting "heat bridge" operated much like an electrical bridge and can be employed in many new and novel heat flow and analysis situations. One application of this new concept heat pipe heat bridge is heat monitoring. Analyses show that one or two simple temperature, wattage, or length measurements will suffice to determine heat flow accurately. The heat pipe heat bridge (HPHB) is a modified version of a gas buffered, variable conductance heat pipe (VCHP) and is, in fact, an infinite set point (ISP) VCHP. The HPHB thus acts as a thermal controller and will function at an infinite number of temperatures, which can be preselected by the operator, or varied during operation to meet variable temperature or heat flux requirements. The HPHB is also an infinite set point heat flow gate and becomes a means to direct heat flows in branching situations. An experimental heat pipe heat bridge was constructed and tested and has verified the principles of operation. Other applications of this new instrument, including its employment as an infinitely variable, feedback control thermal controller, are described.

(HEAT-FLOW, NON-CONDENSIBLE GAS, ISP-VCHP, HEAT MONITORING)

HP77 50025 BOILING LIMITED HEAT PIPES IN A MID-TEMPERATURE RANGE (150 TO 300 C)

Brown, A., (Dept. of Mechanical Engineering and Engineering Production, University of Wales Institute of Science and Technology, Cardiff, Wales), AIChE-ASME Heat Transfer Conference, Salt Lake City, UT, Aug 15-17, 1977, ASME Paper 77-HT-39
Avail:TAC

This paper describes measurements made of evaporator performance for heat pipes with wicks made from two layers of fine wire mesh, one being 100 mesh and the other 400 mesh formed into a polygon section spotwelded to the pipe at the apices of the polygon. Both Thermex and water are used as working fluid. The significant contribution of this paper is in the comparison of the performance of heat pipes with Thermex and water as a working fluid operating under the same conditions. Also for composite wick geometry heat pipes boiling limited evaporation is observed and discussed.

(WICK, WATER, THERMEX, GEOMETRY, WIRE-MESH)

HP77 50026 DYNAMIC TESTING OF A CRYOGENIC HEAT PIPE/RADIATOR

Cenkner, A.A., Jr., (Bell Aerospace TEXTRON, Buffalo, NY), Nelson, B.E., Chuvala, J.T., (Perkin-Elmer Corporation, Danbury, CT), Sixth International Heat Transfer Conf., Toronto, Ontario Canada, Aug 7-11, 1977
Avail:TAC

An experimental investigation was performed to determine the dynamic characteristics of two fixed conductance cryogenic heat pipe/radiators, 1.3 and 6.4 meters long. Included was the response of Freon-13 and nitrogen filled pipes to step changes in evaporator power, as well as response during natural and (evaporator) powered cooldown to the cryogenic regime. Key features of the transient response, subsequent to step power changes that encompassed 2.2 and 62.6 watts (about 87°K to 230°K), include the following: (1) Pipe response was well-behaved with monotonic changes in temperature levels. (2) Once start-up occurred, a relatively large attached distributed mass had a minor effect on pipe performance. (3) Pipe response times for large power changes were fairly long, being measured in hours. (4) It was possible to speed elevation of the pipe temperature by overdriving the evaporator. Preliminary findings on natural cooldown to the cryogenic regime indicated that, under certain conditions, heat pipe/radiators will fail to start naturally as a result of radiator drop-out. Powering of the evaporator during cooldown was shown to be one method of achieving startup. It was also demonstrated that a common Lobar Wick design can be utilized to provide thermal control over an extremely wide temperature range of at least 74-230°K.

(FREON-13, NITROGEN, EVAPORATOR-POWER, COOL-DOWN, START-UP)

HP77 50027 HEAT PIPE RECOVERY SYSTEM STUDY - Final Report

(Dynatherm Corporation, Cockeysville, MD), NAS5-22998, DTM-77-1
Avail:TAC

Industrial process air-to-air heat recovery systems utilizing heat pipes have demonstrated operating performances which are substantially below predicted capabilities.

A study conducted under contract NAS5-22998 has indicated that this inadequate performance is due to liquid-vapor interaction within the heat pipe(s) and recommends experimental investigation of the phenomena. A second phase of the above contract was initiated to investigate the liquid-vapor interaction. A heat pipe design incorporating a viewing port was employed for fluid motion investigations, and tests were conducted with two fluids, various charges, and numerous heat pipe orientations.

(LIQUID-VAPOR, HEAT TRANSFER, BOILING, STABILITY)

HP77 50028 INSTRUMENT CANISTER THERMAL CONTROL

Harwell, W., Haslett, R., (Grumman Aerospace Corporation, Bethpage, NY), Ollendorf, S., (NASA, Goddard Space Flight Center, MD), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-752
Avail:TAC

A transient thermal analysis and test of a thermal control canister is described. The 1 x 1 x 3m canister provides a uniform thermal environment for shuttle instrument payloads requiring fine temperature control, the design goal being operation between 0°C and 20°C with a range of ±1°C at any selected set-point temperature. The canister side walls are isothermalized by a system of longitudinal and circumferential heat pipes rejecting heat through feedback controlled, variable conductance heat pipes to side mounted radiators. A breadboard model of two side walls and two radiators was tested in a thermal vacuum chamber. The breadboard was stable over a wide range of effective environments, experiment dissipations, and control point temperature levels.

(ISOTHERMAL, VCHP, BREADBOARD MODEL)

HP77 50029 PRELIMINARY EVALUATION OF A HEAT PIPE HEAT EXCHANGER ON A REGENERATIVE TURBOFAN

Kraft, G.A., (NASA, Cleveland, OH, Lewis Research Center), Dec 1975, N76-13101
Avail:TAC

A preliminary evaluation was made of a regenerative turbofan engine using a heat pipe heat exchanger. The heat exchanger had an effectiveness of 0.70, a pressure drop of 3 percent on each side, and used sodium for the working fluid in the stainless steel heat pipes. The engine was compared to a reference turbofan engine originally designed for service in 1979. Both engines had a bypass ratio of 4.5 and a fan pressure ratio of 2.0. The design thrust of the engines was in the 4000 N range at a cruise condition of mach 0.98 and 11.6 kM. It is shown that heat pipe heat exchangers of this type cause a large weight and size problem for the engine. The penalties were too severe to be overcome by the small uninstalled fuel consumption advantage. The type of heat exchanger should only be considered for small airflow engines in flight applications. Ground applications might prove more suitable and flexible.

(TURBOJET ENGINE, HEAT EXCHANGER, TESTING, SODIUM, STAINLESS STEEL)

HP77 50030 A PRECISE SATELLITE THERMAL CONTROL SYSTEM USING CASCADED HEAT PIPES

Steele, W.H., (McDonnell Douglas Astronautics Company, St. Louis, MO), McKee, H.B., (Frito-Lay, Inc., Irving, TX), AIAA 12th Thermophysics Conf., Albuquerque, NM, June 27-29, 1977, Paper No. 77-777
Avail:TAC

A cascaded, dry reservoir, variable conductance heat pipe system was tested. Results show passive temperature control within ±0.5°F of the desired set point for a wide range of heat input and effective space environment temperatures. The use of long capillary tubes to isolate the reservoir and prevent set point temperature change due to cyclic heat loads and/or cyclic environment temperature was demonstrated. Orbit set point temperature control feasibility was investigated using variable volume control gas reservoirs. Set point temperature adjustment over a range from 50°F to 90°F was successfully achieved with high control accuracy.

(PASSIVE TEMPERATURE CONTROL, CYCLIC HEAT LOAD, CONTROL ACCURACY)

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